

Optical Performance Monitor

Background of the Invention

1. Field of the Invention.

This invention relates to the field of photonics, and in particular to a monitor for monitoring the performance of photonic devices in an optical network, such as demultiplexers employed in wavelength division multiplexing. The monitor can, for example, accurately measure the power, wavelength, and ONSR (Optical Signal-to-Noise Ratio) for each channel.

2. Description of Related Art

Telecommunications carriers have a need to monitor the performance of optical transport networks. For example, light will often undergo a slight wavelength shift as light source (typically a semiconductor laser) ages and starts to fail. The telecommunications carriers need to be able to monitor this.

A number of manufacturers offer monitoring devices, but none is capable of effectively monitoring channel power, wavelength, and OSNR, and yet at the same time have a small footprint without moving parts and be scaleable. Prior art devices also have limited channel capacity. For example, Kymata Ltd. offers a DWDM Power Monitor that is suitable for active monitoring of optical power levels within a DWDM system. However, this device, which uses AWG (Arrayed Waveguide Grating) technology is not capable of monitoring wavelength or OSNR and is limited to 40 channels. AWG technology has poor scaleability.

Summary of the Invention

According to the present invention there is provided an optical performance monitor for measuring the performance of optical networks, comprising a demultiplexer for demultiplexing an input beam into a plurality of wavelengths; an array of divided output waveguides, each divided output waveguide positioned to receive a corresponding demultiplexed wavelength from said demultiplexer, and each divided output waveguide laterally separating said

corresponding demultiplexed wavelength into a first portion and a second portion; and a detector array having sensor elements positioned to receive said respective first and second portions of said demultiplexed wavelengths.

The demultiplexer is preferably an echelle grating, such as a planar waveguide planar echelle grating, but it could be another demultiplexing device, such as an arrayed waveguide grating, for example. It will be understood that the expression "echelle grating" extends to any "staircase" type grating with staggered facets, including echelon gratings.

The input beam is typically a light beam generated by a laser. It will of course be understood by one skilled in the art that the term "light" in this specification is not limited to light in the visible spectrum.

Directing the demultiplexed wavelengths onto the divided waveguides enables the monitor to be made very sensitive to drift. If the demultiplexed wavelengths have their nominal values, they would typically fall onto the mid-point of the divided output waveguides so that each wavelength is split evenly into the two portions. In the event of drift, the light is no longer split evenly, and by measuring the difference between the outputs of the elements associated with the two portions, very small changes in wavelength can be detected.

The use of undivided waveguides between the divided waveguides allows the measurement of OSNR since the undivided waveguides permit measurement of the background noise.

The echelle grating is preferably a blazed Rowland grating which focuses the demultiplexed wavelengths onto the divided output waveguides.

The output waveguides are preferably ridge waveguides formed by lithography on a substrate also providing a slab waveguide to couple said output waveguides to said echelle grating.

The optical performance monitor can typically measure power, wavelength and OSNR for each channel of an 80 channel system with 50GHz spacing. Other

examples would be 40 channels at 100GHz spacing, and 160 channels at 25 GHz spacing.

In another aspect the invention provides an optical channel monitor comprising a demultiplexer for receiving a beam of incoming light and demultiplexing said incoming light into a plurality of wavelengths; an array of output waveguides, each output waveguide positioned to received a corresponding demultiplexed wavelength from said demultiplexer; and a detector array having sensor elements positioned to receive said respective demultiplexed wavelengths.

While as sensitive to drift such a channel monitor is suitable for measuring the power in the WDM channels, and has considerable advantages over the prior art, particularly with regard to scalability.

The invention also provides a method of monitoring the performance of an optical network, comprising the steps of demultiplexing an input beam into a plurality of wavelengths; receiving said demultiplexed wavelengths in divided output waveguides, said output waveguides separating said demultiplexed wavelengths into laterally spaced portions; and detecting the relative intensity of said laterally spaced portions to determine the drift of said demultiplexed wavelengths from nominal values

Brief Description of the Drawings

The invention will now be described in more detail, by way of example only, with reference to the accompanying drawings, in which:-

Figure 1 is a block diagram of an optical performance monitor;

Figure 2 is a schematic plan view of the spectrometer demultiplexer; and

Figures 3A and 3B are plan views of the spectrometer demultiplexer showing the constructional details.

The optical performance monitor shown in Figure 1 comprises a monolithic spectrometer 10, which will be described in more detail below, an InGaAs array

detector 11, a sweep circuit 12, and a signal processing circuit 13. The signal processing circuit 16 has serial and parallel data outputs.

A temperature sensor 14 monitors the temperature of the device, and a constant temperature at a nominal value is maintained with the aid of thermoelectric cooler 15.

The spectrometer 10 is shown in more detail in Figure 2. This is a monolithic device formed on a glass substrate having etched therein a Rowland circle blazed echelle grating 21. A Rowland grating is described, for example, in the article Planar Rowland Spectrometer for fiber-optic Wavelength Demultiplexing, H.W.Yen, H.R. Friedrich, R.J. Morrison, and G.L.Tangonan, December 1981, Vol. 6, No. 12, Optics Letters. The echelle grating receives a multiplexed input beam containing a number of wavelengths ($\lambda_1, \lambda_2, \dots \lambda_n$) representing channels in a wavelength division multiplexed optical network. There are typically 80 channels with a 50 GHz spacing although an advantage of the present monitor is that it is easily scaleable to handle greater numbers of channels.

The echelle grating 21 demultiplexes the incoming beam and focuses the demultiplexed wavelengths ($\lambda_1, \lambda_2, \dots \lambda_n$) onto an array of output waveguides 23. The output of the echelle grating 21 is coupled through a slab waveguide 22 formed in glass substrate 20.

The output waveguides 23 are ridge waveguides formed by etching and lithographic techniques on the substrate 20. Alternate output waveguides 23', 23'' are evenly divided into first and second split waveguide sections 23a and 23b. The alternate output divided waveguides 23', 23'' are separated by regular undivided waveguides 23.

The output waveguides 23 lead to an InGaAs array detector 24 having individual sensor elements 25 receiving light from each undivided waveguide and split waveguide section.

When components in the input beam have their nominal wavelengths ($\lambda_1, \lambda_2, \dots \lambda_n$), centered on the ITU grid of the telecom window, the waveguide array is

positioned so that they are focused onto the midpoint of the divided waveguides.

In Figure 2, it will be seen that wavelength λ_1 is focused onto the midpoint 26 of divided waveguide 23'' adjacent the leading edge 29a of waveguide divider 29.

As a result the light is divided equally into first and second portions passing
5 respectively through split waveguide sections 23a, 23b, and thus impacts the
corresponds sensor elements 25a, 25b with equal intensity. This is shown by the
55:50 intensity ratio picked up by sensor elements 25a, 25b. It will of course be
realized that it is not necessary for the nominal wavelength to be split 50:50 as
long as the monitor is properly calibrated so that the ratio for the components in
10 each section for each nominal wavelength is known.

In the case of wavelength λ_2 this is assumed to have drifted slightly during its
propagation through the optical network, so that the actual wavelength is now
 $\lambda_2 + \Delta\lambda$. In this case the demultiplexed wavelength will no longer be centered on
the output waveguide 23' but will be slightly offset by an amount that depends
15 on the drift $\Delta\lambda$. In this example it is assume that the drift is such that the light is
split into the two sections in a ratio 80:20.

By measuring the difference in reading between pairs of sensor elements 25a,
25b, it will be seen that the monitor can be made extremely sensitive to very small
amounts of drift $\Delta\lambda$. The monitor can of course measure the drift on a per-
20 channel basis.

The intermediate sensors receive light from the intervening undivided
waveguides 23. These are located at positions where they do not receive a pre-
assigned ITU wavelength demultiplexed by the echelle grating 21 so the only
signal generated by the sensors 25c comes from background noise 28. By
25 comparing the added the signals from the sensors 25a, 25b and comparing the
sum with the signals from the intervening sensors 25c, the monitor can measure
the optical signal-to-noise ratio (OSNR) of the optical network.

If desired the divided waveguides can be omitted and replaced by undivided
waveguides. In this case, the monitor is no longer able to measure wavelength

drift, but it can still measure channel power and OSNR. The use of the echelle grating 21 is desirable because it makes the monitor easily scaleable using monolithic technology. However, AWG systems could also be used for coarser systems.

- 5 In the case of an 80-channel device the described monitor can conveniently use a 256-channel InAsGa array. 160 sensor elements are required for the 80 channels, two for each waveguide, and 79 elements are required for insertion between the divided waveguides (This leaves 17 unused sensor elements). This is a considerable advantage when it is recognized that the cost of a 512-element array
10 required by most prior art systems is about four times the cost of a 256-element array.

- Signal processing is simplified since the wavelength of each channel is measured optically instead of electrically. Signal processing can be carried out using conventional DSP techniques. The use of an echelle grating gives much better
15 resolution than was previously thought possible. The module can also be made smaller.

- Figures 3A and 3B shows the method of construction of the spectrometer for the performance monitor. The echelle grating 21 and output waveguide array are formed monolithically on the glass substrate 20 by etching and lithographic
20 techniques. The echelle grating 21 is associated with a prism compensator region 30 as described in copending application entitled Method for Polarization Birefringence Compensation in a Waveguide Demultiplexer using a Compensator with a High Refractive Index Capping Layer", the contents of which are herein incorporated by reference.

- 25 The input beam is directed at the echelle grating 21 by input waveguide 27 formed as ridge waveguide on substrate 20. Figure 3B shows a 12-wafer die.

The performance of a monitor constructed in accordance with the invention was compared with various commercial prior art devices. The performance and characteristics are set forth in the following table.

Wavelength Range (nm)	S, C, L or 1.3 μ m band
Spectral Resolution (pm)	10
Absolute Wavelength Accuracy(+/-)(pm)	15
Dynamic Range (dB)	60
Absolute Power Accuracy (+/-) (dB)	0.5
Power Range (dBm)	-60 to 0
OSNR (dB, @50GHz)	25
Polarization Dependence (dB)	0.2
Scan time (s)	<1
Power Consumption (W)	5
Electronics Interface	Serial & Parallel
Detectors	256 InGaAs array
Dimensions (mm)	90 x 60 x 22

The optical performance monitor is capable of remote monitoring of power, wavelength, and OSNR for up to 80 channels and offers on-board signal processing. It is remotely upgradeable and can be made to be of very small size.

- 5 It incorporates a high resolution demux, full detector array and signal processor.

Although the invention has been described and illustrated in detail, it is clearly understood that the same is by way of illustration and example only and is not to be taken by way of limitation, the spirit and scope of the present invention being limited only by the terms of the appended claims.